Vswr and impedance matching techniques pdf

In order for the radio (transmitter or receiver) to supply energy to the antenna, the impedance of the radio and transmission line must be well adapted to the impedance of the antenna. The VSWR parameter is a measure that numerically describes how well the antenna is impedance, adapted to the radio or transmission line to which it is connected. VSWR stands for Voltage Standing Wave Ratio and is also referred to as standing wave ratio (SWR). VSWR is a function of the reflection coefficient that describes the power reflected from the antenna. If the reflection coefficient is given by point , VSWR is defined by the following formula: The reflection coefficient is also referred to as s11 or loss of return. In the following vswr table, you will see a numerical mapping between reflected performance, s11, and VSWR. If you don't want to go through complex equations to understand the relationship between VSWR, loss of mismatch, s11/gamma, and would like a calculator to do it for you, check out our VSWR calculator page and we'll convert VSWR for you. VSWR is always a real and positive number for antennas. The smaller the VSWR, the better the antenna is adapted to the transmission line and the more power is supplied to the antenna. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal. Antennas often have to meet the bandwidth requirement that is listed from the point of view of VSWR. For example, the antenna can claim to operate from 100-200 MHz with VSWR VSWR is determined from the voltage measured along the transmission line leading to the antenna. VSWR is the ratio of the amplitute of the peak of the standing wave to the minimum amplitute of the standing wave, as shown in the following figure: Figure 1. Voltage measured along the transmission line. In the industry, VSWR is sometimes pronounced see-wer. If the antenna is not paired with the receiver, the power is reflected (so the reflection coefficient, , is not zero). This causes a reflected voltage wave, which creates standing waves along the transmission line. The result is peaks and valleys, as shown in Figure 1. If VSWR = 1.0, there would be no reflected power and the voltage would have a constant size along the transmission line. VSWR, Reflected Performance, and S11 Is VSWR 3 Bad? How bad is VSWR 12? Well, there are no hard rules. In this section, we will try to put the VSWR number into context. Below is a table showing the relationship between VSWR, total reflected power and (also known as s11) and total reflected power. Note that reflected power is simply a quadratic reflection coefficient () . Table I. VSWR, reflected power and (s11) VSWR (s11) Reflected power (%) Reflected power (dB) 1.0 0.000 0.00 -Infinity 1.5 0.200 4.0 -14.0 2.0 0.333 2 11.1 -9.55 2.5 0.429 18.4 -7.36 3.0 0.500 25.0 -6.0 3.5 0.556 30.9 -5.10 4.0 0.600 36.0 -4.44 5.0 0.667 144.0 -3.52 6.0 0.714 51.0 -2.92 7.0 0.750 56.3 -2.50 0.778 60.5 -2.18 9.0 0.800 64.0 -1.94 10.0 0.818 66.9 -1.74 15.0 20.875 76.6 -1.5 16 20.0 0.905 81.9 -0.87 50.0 0.961 92.3 -0.35 In the table above and VSWR 4 has 36% of the energy supplied by the receiver reflected from the antenna (64% of the energy is supplied to the antenna). Note that reflected power of 0 dB means that all performance (100%), while -10 dB means that 10% of performance is reflected. If all performance is reflected, VSWR would be infinite. Note that VSWR is a highly nonlinear function of the reflection coefficient . This means that there is very little difference in reflected performance when vswr increases from 9 to 10; however, if the VSWR system changes from 1 to 2, there will be an 11% change in reflected power. In general, if the VSWR is below 2, the antenna is considered very good and few would be obtained by the same impedance. As VSWR increases, there are 2 main negatives. The first is obvious: more energy is reflected from the antenna, and therefore not transmitted. However, another problem arises. As vswr increases, more energy is reflected on the radio it broadcasts. A large amount of reflected current can damage the radio. In addition, radios have difficulty transmitting the correct information bits when the antenna is poorly paired (this is numerically defined in terms of another metric, EVM - Error Vector Magnitude). VSWR specifications for antennas Often in industry, antennas are tested (compliance/non-compliance criteria) based on VSWR (VSWR specifications). This is a method of passive measurement of antennas to see if they are quickly tuned correctly. The antenna is measured using a network analyzer and VSWR as a frequency function is recorded. As an example, consider this situation where 5 VSWR antennas are measured and rendered, along with 4 lines that represent the VSWR specifications for this antenna (in blue): Figure 2. Plot 5 antennas VSWR versus Frequency. The VSWR specifications in Figure 2 are defined by: (1) VSWR < 3.8 for 825MHz < f < 910 MHz (2) VSWR > 4.0 for 1200MHz < f < 1400 MHz (3) VSWR > 3.0 at f = 1.7 GHz, linearly reduced to VSWR > 2.0 at f = 1.8 GHz (4) VSWR < 3.0 for 1860 MHz < f < 2000 MHz in Figure 2, the red antenna of the VSWR curve would fail at the second specification, and the light blue antenna of the VSWR curve would (marginally) not meet the fourth specification. This is shown in Figure 3: Figure 3. VSWR specifications and VSWR curves. Setting the VSWR specification is a rather tricky job for antenna engineers. The goal is to fail remote values (detuned antennas or antennas with broken connectors, etc.). In practice, however, it is difficult to determine what is an acceptable deviation, especially in high-volume industries, where a tefy specification could fail thousands of good antennas. Note that VSWR is a measure of how much power is supplied to the antenna. This does not mean that the antenna emits all the energy VSWR therefore measures the potential to emit. Low VSWR means that the antenna is well aligned, but does not necessarily mean that the supplied power is also emitted. To determine the power emitted, a non-impact chamber or other test of the antenna emitted is required. VSWR alone is not enough to determine the correct operation of the antenna. VSWR can also be measured on the Smith Chart. VSWR is only a scalar measurement, while the Smith diagram shows both size and phase. For more details, see the Smith Chart page. Above: VSWR Home antenna definition: Antenna-Theory.com (Home) This page on VSWR (Voltage Standing Wave Ratio) is copyrighted. No part can be reproduced, except permission from the author. Copyright antenna-theory.com, 2009-2017, VSWR. This book begins with a practical description of important quantities such as VSWR, reflection coefficient, loss mismatch, etc. It also describes a practical way to perform impedance compliance in wireless/RF and other electronic circuits for a student and practicing engineer. Starting with a simple L- match and Smith charts on more complex techniques. A set of Javascripts are also available as an aid to understanding the technique, and can be purchased separately from the associated web page. In radio and telecommunications, the standing wave ratio (SWR) is a measure of impedance load compensation with characteristic impedance of the transmission line or wavelength. Impedance wave mismatch leads to wave standing along the transmission line, and SWR is defined as the ratio of the partial standing wave amplitude at the antinode (maximum) to the amplitide in the node (minimum) along the line. SWR is usually considered in terms of maximum and minimum alternating voltage along the transmission line, i.e. called the standing voltage wave ratio or VSWR (sometimes pronounced vizwar[1][2]). For example, A VSWR value of 1.2:1 indicates that the alternating stress caused by stagnant waves along the transmission line will have a maximum value of 1.2 times the minimum ALTERNATING voltage value along that line, provided that the line is at least half a wavelength long. SWR can be defined as the ratio of the maximum amplitute to the minimum amplitute of transmission line currents, electric field force or magnetic field force. Neglecting the loss of transmission lines, these ratios are identical. The standing ratio (PSWR) is defined as the square of VSWR,[3] but this outdated terminology has no physical relation to the actual powers associated with transmission. SWR is usually measured using a special device called an SWR meter. Since SWR is a measure of load impedance due to the characteristic impedance of the usable transmission line (which together determine the reflection coefficient as described below), the SWR can interpret the impedance it sees only from the point of view of the SWR if it has been characteristic impedance. In practice, most transmission lines used in these applications are coaxial cables with impedance of either 50 or 75 ohms, so most SWR meters correspond to one of them. Checking SWR is standard procedure in a radio station. Although the same information can be obtained by measuring load impedances using an impedance analyzer (or impedance bridge), the SWR meter is simpler and more robust for this purpose. By measuring the size of the impedance mismatch at the transmitter output, it reveals problems caused either by the antenna or by the transmission line. Impedance corresponding Main Article: SWR impedance pairing is used as a measure of impedance load adjustment with characteristic impedance of the transmission line carrying radio frequency signals (RF). This applies in particular to transmission lines connecting radio transmitters and receivers with their antennas, as well as similar uses of RF cables, such as cable TELEVISION connections to television sets and distribution amplifiers. Impedance compliance is achieved when the impedance source is a complex conjugate impedance load. The easiest way to do this, and a way to minimize losses along the transmission line, is for the imaginary part of the complex impedance of both the source and the load to be zero, i.e. pure resistances equal to the characteristic impedance of the transmission line. If there is a mismatch between the load impedance and the transmission line, the part of the front wave sent towards the load shall be reflected back along the transmission line towards the source. The source then sees a different impedance than expected, which can lead to less (or in some cases more) power supply that is supplied, which is very sensitive to the electrical length of the transmission line. Such a mismatch is usually undesirable and leads to a wave standing along the transmission line, which increases the loss of transmission lines (significant at higher frequencies and for longer cables). SWR is a measure of the depth of these waves standing up and is therefore a measure of the alignment of loads with transmission lines. The corresponding load would result in an SWR of 1:1, which would mean no reflected wave. Infinite SWR represents a complete reflection of a load that is unable to absorb electricity, with all incident power reflected back to the source. It should be understood that the conformity of the load with the transmission line differs from the conformity of the source with the transmission line or the conformity of the source with the load seen through the transmission line. For example, if there is a perfect match between zload load impedance and Zsource impedance = Z* load, that perfect match will remain if the source and load are connected via a transmission line with an electrical length of one half of the wavelength (or one half of the wavelengths) by means of a transmission line of any characteristic impedance Z0. However, SWR generally will not be 1:1, depending only on Zload and Z0. With a different length of transmission line, the source will see an impedance other than Zload, which may or may not be a good match to the source. Sometimes it's intentional, as when a quarter wave corresponding section is used to improve the match between an otherwise mismatched source and a load. However, typical RF sources, such as transmitters and signal generators, are designed to look into pure resistance impedance loads such as 50Ω or 75Ω, which corresponds to the characteristic impedance of conventional transmission lines. In these cases, the corresponding load on the transmission line, Zload =Z0, always ensures that the source sees the same load impedance as if the transmission line was not there. This is identical to 1:1 SWR. This condition (Zload=Z0) also means that the load that the source sees is independent of the electrical length of the transmission line. Since the electrical length of the physical transmission line segment depends on the frequency of the signal, a violation of this condition means that the impedance that the source sees through the transmission line becomes a function of the frequency (especially if the line is long), even if the Zload is frequency-independent. So in practice, a good SWR (near 1:1) means transmitter output to see the exact impedance that it expects for optimal and safe operation. The relationship to the incident wave reflection coefficient (blue) is fully reflected (red wave) outside the phase at the short-circuit end of the transmission line, which creates a network (black) standing wave. Γ = −1, SWR = ∞. Standing waves on the transmission line, net voltage displayed in different colors during one period of oscillation. The incoming wave from the left (amplitude = 1) is partially reflected with (top to bottom) Γ = 0.6, −0.333 and 0.8 ∠60°. Resulting SWR = 4, 2, 9. The voltage component of the standing wave in an even transmission line consists of the front wave (with a complex amplitude V f {\displaystyle V_{f}}) overlapping with the reflected wave (with complex amplitude V r {\displaystyle V_{r}}). The wave is partially reflected when the transmission line is terminated by a line other than impedance equal to its characteristic impedance. The reflection coefficient Γ {\displaystyle \Gamma } can be defined as: Γ = V r V f . {\displaystyle \Gamma ={\frac {V_{r}}{V_{f}}}.} or Γ = Z L − Z O Z L + Z O {\displaystyle \Gamma ={Z_{L}-Z_{O} \over Z_{L}+Z_{O}}} Γ {\displaystyle \Gamma } is a complex number that describes both the size and phase shift of the reflection. The simplest cases with Γ {\displaystyle \Gamma } measured under load are: Γ = − 1 {\displaystyle \Gamma =-1} : complete negative reflection when the line is shorted, Γ = 0 {\displaystyle \Gamma =0} : without reflection, the line is perfectly aligned, Γ = + 1 {\displaystyle \Gamma =+1} : a complete positive reflection when the line is open. SWR directly corresponds to the Γ {\displaystyle \Gamma } . At some points along the forward line and reflected waves constructively intervene, precisely at the stage, with the resulting amplitude V max {\displaystyle V_{\text{max}}} given by the sum of the amplitudes of the following waves: | In max | = | In f | + | In r | = | In f | + | Γ V f | = (1 + | Γ |) | In f | . {\display style {\begin{aligned}| V_{\text{max}}|||| V_{f}|+| V_{r}|\\&=| V_{f}|+|\Gamma V_{f}|\\&1+|\Gamma |)| V_{f}|. \end{aligned}}} At other points, waves extend 180° outside the phase with partial cancellation of amplitudes: | In min | = | In f | − | In r | = | In f | − | Γ V f | = (1 − | Γ |) | In f | . {\display style {\begin{aligned}| V_{\text{min}}|| =| V_{f}|-| V_{r}|\\&=| V_{f}|-|\Gamma V_{f}|\\&1-|\Gamma |)| V_{f}|. \end{aligned}}} The ratio of standing voltage waves is then VSWR = | In max | | In min | = 1 + | Γ | 1 − | Γ | . {\displaystyle {\text{VSWR}}={\frac {| V_{\text{max}}|} {| V_{\text{min}}|}} ={\frac {1+|\Gamma |} {1-|\Gamma |}}.} Because the size of the Γ {\displaystyle \Gamma } always falls within the range [0.1], the SWR is always greater than or equal to unity. Note that phases Vf and Vr vary along the transmission line in opposite directions. Therefore, the reflection coefficient differs with the complex value Γ {\displaystyle \Gamma }, but only in the phase. With SWR dependent only on complex size Γ {\displaystyle \Gamma }, you can see that the SWR measured at any point along the transmission line (neglecting transmission line losses) gets the same read. Since the forward and reflected wave power is proportional to the square power of the voltage components as a result of each wave, SWR can be expressed forward and reflected power: SWR = 1 + P r / P f 1 − P r / P f . {\displaystyle {\text{SWR}}={{frac {1+{\sqrt {P_{r}/P_{f}}}}{1-{\sqrt {P_{r}/P_{f}}}}}}}} Sampling of complex voltage and current at the insertion point, the SWR meter is able to calculate the effective forward and reflected voltage on the transmission line for the characteristic impedance for which the SWR meter was designed. Because forward and reflected power is related to the square of the front and reflected voltages, some SWR meters also display forward and reflected power. In the specific case of the RL load, which is purely durable but uneven, the characteristic impedance of the Z0 transmission line, SWR is determined simply by their ratio: SWR = (R L Z 0) ± 1 {\displaystyle {\text{SWR}}=\left({\frac {R_{\text{L}}}{Z_{\text{0}}}}\right)^{pm1}} with ±1 selected to get a value greater than unity. Pattern of stagnant waves The use of complex notation for stress amplitdes, for at the frequency ν {\displaystyle u } the actual (actual) voltage Vactual as a function of time t means the relation to complex stresses according to: V actual = R (e i 2 π ν t V) {\displaystyle V_{\text{actual}}=Re (e^{i2\pi u t}V)} . Thus, with a fair portion of the complex quantity inside the parentheses, the actual stress consists of a sine wave at a frequency of ν with a peak amplitude equal to the complex size V, then with the position along the transmission line given x, with the line ending with the load located on x0, the complex amplitdes of the front and return waves would be written as follows: In f (x) = e − i k (x − x 0) And In r (x) = Γ e i k (x − x 0) A {\displaystyle {\begin{aligned}V_{f}(x)&=e^{-ik(x-x_{0})}A\\V_{r}(x)&=\Gamma e^{ik(x-x_{0})}A\end{aligned}}} for some complex amplitudes A (corresponding to the front wave at x0). Here k is the wavelength due to the controlled wavelength along the transmission line. Note that some procedures use phasory, where the time dependency by e − i 2 π ν t {\displaystyle e^{-i2\pi for t}} and spatial dependency (for wave in direction +x) e + i k (x − x 0) {\displaystyle e^{+ik(x-x_{0})}} . Either convention gets the same result for Vactual. According to the principle of superposition, the mains voltage present at any point x on the transmission line is equal to the sum of the voltage due to the front and reflected waves: V net (x) = V f (x) + V r (x) = e − i k (x 0) (1 + Γ e i 2 k (x − x 0)) And {\displaystyle {\begin{aligned}V_ Γ <6>{\text{net}}(x)&=V_{f}(x)+V_{r}(x)\\\e^{-ik(x-x_{0})}}left(1+\Gamma e^{i2k(x-x_{0})}\right)A\end{aligned}}} Due to because we are interested in variants of the size of the virtual network along the line (as a function x), we will solve instead for the quadrate size of this amount, which simplifies mathematics. To obtain the quadrature, multiply the above amount by its complex conjugate: | In network (x) | 2 = V net (x) V net ∗ (x) = e − i k (x − x 0) (1 + Γ e i 2 k (x − x 0)) A e + i k (x - x 0) (1 + Γ ∗ e − i 2 k (x − x 0)) A ∗ = [1 + | Γ | 2 + 2 R (Γ e i 2 k (x - x 0)]] | A | 2 {\display style {\begin{aligned}| V_{\text{net}}(x)|^{2}& V_{\text{net}}(x)V_{\text{net}}^{}(x)\\&e^{-ik(x-x_{0})}}left(1+\Gamma e^{{i2k(x-x_{0}}\right)A \,e^{+ik(x - x_{0})}\left(1+\Gamma ^{*}e^{{-i2k(x-x_{0})}\right)A^{*}\\left[1+|\Gamma |^{2}+2\Re (\Gamma e^{i2k(x-x_{0})})\right] A|^{2}\end{aligned}}} Depending on the stage of the third term, the maximum and minimum values of the virtual network network (square root quantity in equations) (1 + |Γ|)| A| and (1 − |Γ|)| A| for standing wave ratio: SWR = | In max | | In min | = 1 + | Γ | 1 − | Γ | {\displaystyle {\text{SWR}}={\frac {1+|\Gamma |} {1-|\Gamma |}}} as previously claimed. Along the line, the above expression for | In network (x) | 2 {\display style | V_{\text{net}}(x)|^{2}} you can see that between | In min | 2 {\display style | V_{\text{min}}|^{2}} and | In max | 2 {\display style | V_{\text{max}}|^{2}} with a period of 2π/2k. This is half the controlled wavelength λ = 2π/k for the frequency ν. This can be seen as a result of interference between two waves of this frequency, which take in the opposite direction. For example, at a frequency of ν=20 MHz (free space wavelength of 15 m) in the transmission line, whose speed factor is 2/3, the guided wavelength (the distance between the peaks of the stress of the front wave itself) would be λ = 10 m. In cases where the front wave at x = 0 is in the zero phase (peak voltage), then at x = 10 m it would also be in the zero phase, but at x = 5 m it would be in the 180° phase (peak negative voltage). On the other hand, the voltage size due to the stagnant wave produced by its addition to the reflected wave, the wavelength between the peaks should be only λ/2 = 5 m. Depending on the location of the load and the stage of reflection, the tip in the size of Vnet at x = 1,3 m. Then there would be another peak found where | Vnet|=Vmax at x = 6.3 m, while finding lows standing waves | Virtual network| = Vmin at x = 3.8 m, 8.8 m, etc. Practical implications of SWR Example of estimated antenna bandwidth according to the VSWR plan using ANSYS HFSS[4] The most common case for measuring and examining SWR is when installing and debugging transmitting antennas. When the transmitter is connected to the antenna by a power channel, the impedance of the antenna drive point shall correspond to the characteristic impedance of the power line so that the transmitter can see the impedance for which it was designed (impedance of the power line, usually 50 or 75 ohms). The impedance of a particular antenna design may vary depending on a number of factors that cannot always be clearly identified. This includes the frequency of the transmitter (compared to the antenna structure or resonant frequency), the height of the antenna above and the quality of the ground, the proximity of large metal structures and changes in the exact size of the wires used to produce the antenna. [5] If the antenna and power lines do not have adequate impedance, the transmitter sees an unexpected impedance where it may not be able to produce full power and in some cases may even damage the transmitter. [6] Reflected power in the transmission line increases the average current and thus the losses in the transmission line compared to the power actually delivered to the load. [7] It is the interaction of these reflected waves with the front waves that causes patterns of standing waves,[6] with the negative consequences that we have observed. [8] Impedance match to impede the power line can sometimes be done by adjusting the antenna itself, but otherwise it is possible using an antenna tuner, which is an impedance device. Installing the tuner between the power channel and the antenna allows the power line to see a load close to its characteristic impedance, while most of the transmitter's power (a small amount can be scattered inside the tuner) to be emitted by the antenna despite its otherwise unacceptable impedance to the power point. Installing a tuner between the transmitter and the power channel can also convert the impedance at the end of the transmitter into a transmitter, the preferred transmitter. In the latter case, however, the feed line still has a high presence of steel cables, with the resulting increased losses of the power line being total. The magnitude of these losses depends on the type of transmission line and its length. They always increase with frequency. For example, a certain antenna, which is used away from the resonant frequency, can have an SWR of 6:1. For a frequency of 3.5 MHz, with an antenna powered by over 75 meters of coaxial RG-8A, the loss caused by standing waves would be 2.2 dB. However, the same 6:1 mismatch over 75 meters of RG-8A coaxial cable would result in a loss of 10.8 dB at 146 MHz.[6] Better antenna-to-power channel compliance, i.e. lower SWR, it becomes increasingly important with increasing frequency, even if the transmitter is able to accommodate the seen impedance (or the antenna tuner can be seen between the transmitter used and the power line). Some types of transmissions may suffer from other negative effects of reflected waves on the transmission line. Analog TV can experience ghosts from delayed signals that bounce back and forth on a long line. Fm stereo may also be affected and digital signals may experience delayed pulses leading to bit errors. Whenever the delay times of a signal that returns down and then up again are comparable to the time constant modulation, effects occur. For this reason, these types of transmissions require low SWR on the feed line, even if the swr would cause a loss and the match is performed on the transmitter. Methods of measuring the ratio of stagnant waves Grooved line. The probe moves along the line to measure the variable stress. SWR is the maximum divided by the minimum voltageMeas of different methods can be used to measure the ratio of standing waves. The most intuitive method uses a grooved line, which is the part of the transmission line with an open slot that allows the probe to detect the actual stress at different points along the line. [9] This allows you to directly compare the maximum and minimum values. This method is used on VHF and higher frequencies. At lower frequencies, such lines are impractically long. Directional couplings can be used at HF via microwave frequencies. Some of them are a quarter of a wave or more long, limiting their to higher frequencies. Other types of directional couplers take current and voltage at one point of the transmission path and mathematically combine them to represent the force flowing in one direction. [10]. A common type of SWR/power meter used in amateur operation may contain a two-way coupler. Other types use a single coupler that can be rotated 180 degrees to make a sample of energy flowing in both directions. One-way couplings of this type are available for many frequency ranges and outputs and with corresponding connection values for the analogue meter used. A directional wattmeter using the swivel directional coupler element Front and reflected power measured by directional couplings can be used for the calculation of SWR. Calculations may be made mathematically in analog or digital form or by means of graphical methods incorporated into the meter as an additional scale or by subtracting from the boundary crossing between two needles on the same meter. The above measuring instruments can be used in a series, that is, the full power of the transmitter can pass through the measuring device to allow continuous monitoring of the SWR. Other instruments, such as network analyzers, low-power directional couplings and antenna bridges, consume low power for measurement and must be connected instead of the transmitter. Bridge circuits can be used to directly measure actual and imaginary parts of load impedance and to use these values to derive SWR. These methods can provide more information than just SWR or forward and reflect performance. [11] Separate antenna analyzers use different measurement methods and can display SWR and other parameters plotted against frequency. Using directional couplers and a bridge in combination, it is possible to create an in-line device that reads directly in complex impedance or in SWR. [12] Separate antenna analyzers are also available that measure multiple parameters. Standing wave ratio The term standing wave ratio (PSWR) is sometimes referred to as the sophomore ratio of stagnant stress waves. The term is widely cited as misleading. [13] In Gridley's words:[14] The term stagnant wave ratio sometimes encountered is even more misleading because the distribution of energy along the lossless line is constant.....— J.H. Gridley Nonetheless corresponds to one type of SWR measurement using what was previously a standard measuring instrument on microwave frequencies, grooved line. A grooved line is a wavelength (or air-filled coaxial line) in which a small sensing antenna that is part of a crystal detector or detector is placed in an electric field in a row. The voltage induced in the antenna is rected either by a point contact diode (crystal rector) or by the Schottky barrier diode, which is part of the detector. detectors have a square legal output for low input levels. The values therefore corresponded to the squares of the electric field along the groove, E2(x), with the maximum and minimum values E2max and E2min found when the probe moved along the groove. The ratio of these yields to the square of SWR, the so-called [15]. This technique of rationalizing concepts is fraught with problems. [it should be clarified] The square legal behavior of the detector diode is exposed only when the voltage across the diode is below the knee of the diode. As soon as the detected voltage crosses the knee, the response of the diode becomes almost linear. In this mode, the diode and its associated filter capacitor produce a voltage that is proportional to the tip of the sampled voltage. The operation of such a detector would not have a ready indication as to the mode in which the detector diode is in operation and therefore it is not practical to distinguish the results between steel ropes or so-called steel ropes. Perhaps even worse is the common case when the minimum detected tension is below the knee and the maximum tension is above the knee. In this case, the calculated results are largely meaningless. The concepts of PSWR and Power Standing Wave Ratio are therefore obsolete and should only be assessed in terms of lifted measurements. The impact of steel ropes and cables on medical SWR applications can also have a detrimental impact on the performance of microwave-based medical applications. In microwave electrosurgery, an antenna placed directly into the tissue may not always have optimal compliance with the power cord, resulting in SWR. The presence of steel ropes and cables may affect the monitoring components used to measure performance levels that affect the reliability of these measurements. [16] See also Return loss Reflector time-domain SWR meter Impedance Mismatch loss Total active reflection coefficient Reference ^ Knott, Eugene F.; Shaeffer, John F.; Tuley, Michael T. (2004). Radar cross-section. SciTech Radar and Defense Series (2nd ed.). SciTech Publishing. p. 374. ISBN 978-1-891121-25-8. ↑ Schaub, Keith B.; Kelly, Joe (2004). Production testing of RF and system devices on the chip for wireless communication. Artech House Microwave Library. Artech House. p. 93. ISBN 978-1-58053-692-9. ^ Samuel Silver, Theory and Design of Microwave Antennas, p. 28, IEE, 1984 (originally published 1949) ISBN 0863410170 ^ I. Sliusar, V. Slyusar, S. Voloshko, A. Zinchenko, Y. Utkin. Synthesis of broadband ring antenna two-tape design. 12th International Conference on Antenna Theory and Techniques (ICATT-2020), 22- 27 June 2020, Kharkiv, Ukraine. ^ Hutchinson, Chuck, ed. (2000). ARRL Manual for Radio Amateurs 2001. Newington, CT: ARRL-National Association for Amateur Radio. p. 20.2. ISBN 978-0-87259-186-8.CS1 maint: next text: list of authors (reference) ^ and b c Hutchinson, Chuck, ed. (2000). ARRL Guide for Amateurs 2001. Newington, CT: ARRL-National Association for Amateur Radio. 19.4-19.6. ISBN 978-0-87259-186-8.CS1 maint: next text: list of authors (link) ^ Ford, Steve (April 1994). Obsession with SWR (PDF). Qst. Newington, CT: ARRL-National Association for Amateur Radio. 78 (4): 70–72. They were acquired in 2014-11-04. ↑ Hutchinson, Chuck, ed. (2000). ARRL Manual for Radio Amateurs 2001. Newington, CT: ARRL-National Association for Amateur Radio. p. 19.13. ISBN 978-0-87259-186-8.CS1 maint: next text: list of authors (link) ^ Fredrick E. Terman, Electronic Measurements, McGraw Hill, 1952 Library of Congress catalog number: 51-12650 p.135ff ^ How the SWR meter really works. Glenn B. Schulz W9IQ. January 24, 2018. Taken March 18, 2018. ↑ Nautel adds two models to the NX series. Nautel. March 11, 2015. 6 July 2017. ↑ Delta Electronics, Inc. Model OIB-1 and OIB-3. www.deltaelectronics.com. ^ Christian Wolff, Standing Wave Ratio, radartutorial.eu ^ J. H. Gridley, Principles of Electrical Transmission Lines in Power and Communication, p. 265, Elsevier, 2014 ISBN 1483186032. ↑ Bernard Vincent Rollin, Introduction to Electronics, p. 209, Clarendon Press, 1964 OCLC 1148924. ↑ Problems with VSWR in medical applications. microwaves101.com. Won July 6, 2017. Further reading Understanding the basic principles of vector network analysis, Hewlett Packard 1287-1 Note, 1997 External References Permanent Wave diagram Web application, which draws a diagram of constant waves and calculates SWR, input impedance, reflection coefficient and other reflection and VSWR Flash sample of transmission line reflection and SWR VSWR - online conversion tool between SWR, coefficient of loss of return and reflection Online Calculator VSWR VSWR tutorial series of pages dealing with all aspects of VSWR, reflective coefficient, loss of return, practical aspects, measurement, etc. Loaded from