MEASUREMENTS IN THE RADIOFREQUENCY RANGE ON ABSORBING AND SHIELDING MATHERIALS

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Abstract-The paper describes methods and the dedicated instrumentation set-up used for characterization the behaviors of the absorbing materials. The described methods are based on the free space measurement with a receiving/transmitter antenna and a directional coupler as an ending path of the vector analyzer. Various methods are tested for cancellation of the unwanted signals and for an adequate characterization of the true reflection/absorption coefficients for composite materials and Salisbury screen.

I. Introduction

A usually method that allows broad-band measurements uses the free-space technique. This method allows obtaining of the specific parameters for absorbing and shielding materials having large size and it can be applied in both time and frequency domain. This class of measurements requires two identical antennas for transmission/reception, but using a single perfectly adapted antenna together with a high-directivity directional coupler, some problems arisen from the incident/reflected angles determination being avoided. Two steps are necessary in this kind of measurements: with sample under test, SUT, and with a very good reflective surface substituted in the same place as SUT [1].

II. Instrumentation set-up

The measuring system can be developed around on a Vector Analyzer working as vector voltmeter, Fig. 1. The RF signal generated by the generator is transmitted toward the target – SUT or Reflective Panel, RP – through a high directivity directional coupler and a Horn antenna. The SUT is a slab bordered by absorbing materials. In this manner, the reflected traveling waves is constituted in most part from the same front wave [2] which was reflected by the backplane of the SUT or by the RP.

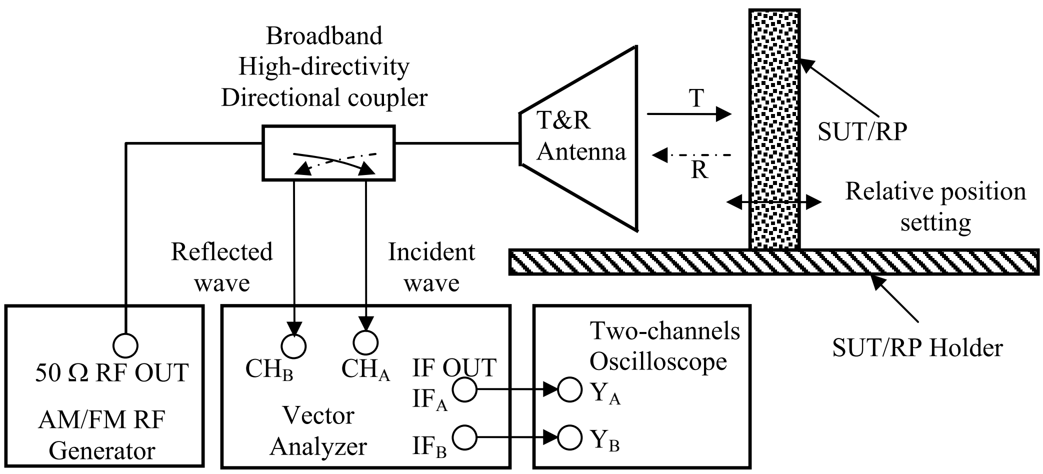

Fig. 1. Single antenna free-space reflection measurement method: the instrumentation set-up

The directional coupler gives two output signals leads on the incident and reflected waves. These signals are visualized on a two channels oscilloscope in the intermediary frequency form, IF, achieved from the IF outputs of the Vector Analyzer. The frequency of these signals is around 20 kHz independently from the test frequency and their waveform quality and their phase will validate the rightness of the measurements.

If $\boldsymbol{E}_{i1}$ - $\boldsymbol{E}_{r1}$ are the transmitted and reflected electric field components [3] in the RP case, $\boldsymbol{E}_{i2}$ - $\boldsymbol{E}_{r2}$ in the SUT case, the measurement results, obtained at the output ports of the directional coupler V_A – V_B , then it can be determine the contribution of the SUT using a relative calculus:

$$RE_{[dB]} = 20\log\left(\frac{E_{r1}}{E_{i1}} : \frac{E_{r2}}{E_{i2}}\right) = 20\log\left(\frac{V_{B1}}{V_{A1}} : \frac{V_{B2}}{V_{A2}}\right) \quad (1)$$

The first major condition is to be realized the best matching for all sections connected on the path between RF generator and T/R antenna, also at the free-space interface and at the directional coupler output ports [4]. This condition can be verified by an unloaded free-space measurement, when the reflected wave must be insignificant.

Another important condition is to have a very good separation between reflected waves from various places and the wanted reflected wave. A good waveform of the voltage related on the reflected wave and a stable phase shift, depends on the relative position of the SUT or RP, proves the fulfilling of this last requirement [5].

The dynamic range is upper limited by the directivity of the directional coupler through by the subunitary ratio representing the receiving/transmitting antenna gain. For a directivity of 36 dB we expect to characterize absorbers having the reflection coefficient about 10 dB smaller.

The previous instrumentation set-up can be a little bit changed by introducing a probe field antenna, Fig. 2. A broadband electric stick antenna can collect the resulting field in various situations: unloaded free space, full reflective panel RP load and with the SUT absorber load. The role of the directional coupler is now the furnishings of the necessary canceling signal established in the first phase of the measurement. Based on the scope facilities, the reversing phase is not necessary until it. After minimize the result $Y_B + (-Y_A)$ by changing the attenuation of the incident wave signal, it can be measure the contribution of the two equivalent surface of the panel or slab [6]. Their ratio will have as result the reflection coefficient of the SUT:

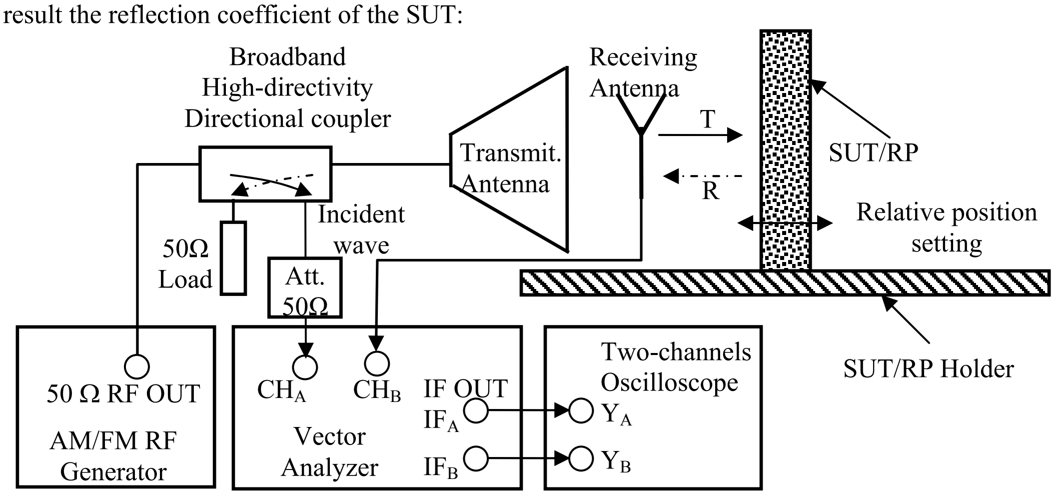

Fig. 2. Free-space reflection measurement method: field probe method.

$$[Y_B + (-Y_A)]_I = \min, [Y_B + (-Y_A)]_{II} = KE_{rm}, [Y_B + (-Y_A)]_{III} = KE_r \Rightarrow$$

$$RE_{[dB]} = 20\log\left(\frac{[Y_B + (-Y_A)]_{II}}{[Y_B + (-Y_A)]_{III}}\right) \quad (2)$$

III. Continuous wave variable-screen modulator principle

A screen having a variable reflection can be placed in front of the SUT. This device, VS, can produce a modulation having known frequency and the result depending by the SUT reflection coefficient. The variable screen consists in a 2D rectangular curtains array able to have a spin around of their symmetry axes, Fig. 3. If the motor speed is *n* revolutions per minute, then the modulation signal will have the frequency: $f_{mod} = 2\, n/60 = n/30$.

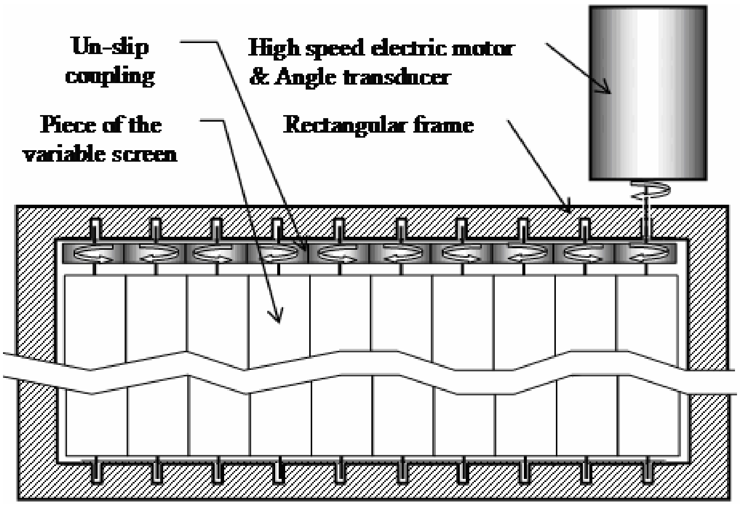

Fig. 3. The variable screen.

For an electric motor having the speed adjusted at 1800 rev./min., the modulated signal will have the envelope of 60 Hz. This signal must be detected after prior selective narrow-band amplification followed by a scaling for known condition. This case can be the free space one. The instrumentation set-up will show like in Fig. 4. The variable screen VS has the curtain rotation axes in a median plane situated at about 10 mm from SUT, insignificant considered for the far field measurements case, centered on the antennas longitudinal plane.

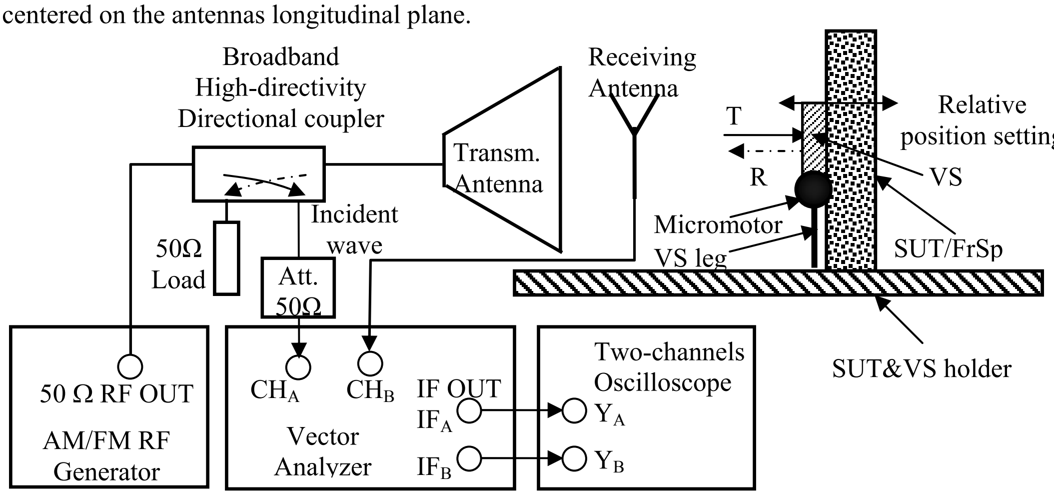

Fig. 4. Free-space reflection measurement method: variable screen method.

The reflected wave will became an AM wave one having the maximum and the minimum corresponding to the perfect reflective and perfect transparent state of VS, respectively. The non-modulated signal must be canceled by adjusting the attenuation of the incident wave in the same manner as previous case. In the second step on the oscilloscope screen will appear the AM wave produced by the VS and SUT. The SUT reflection coefficient will be obtained from the resulting oscilloscope representation characterized in two extreme values of the waveform, minimum and maximum, as following:

$$\left[Y_B + (-Y_A)\right]_I = \min \Rightarrow RE_{[dB]} = 20\log\left(\left.\frac{\left[Y_B + (-Y_A)\right]_{\min}}{\left[Y_B + (-Y_A)\right]_{\max}}\right|_{II}\right) \tag{3}$$

The AM depth m_{VS} defined for the maximum and minimum values, a and b respectively, can be related directly from the wanted parameter $RE_{[\mathrm{dB}]}$ by the next formulas:

$$m_{\mathrm{VS}} = \frac{a-b}{a+b} = \frac{1-RE}{1+RE} \Rightarrow RE_{[dB]} = 20\log\left(\left.\frac{1-m_{\mathrm{VS}}}{1+m_{\mathrm{VS}}}\right|_{II}\right) \tag{4}$$

A reflection coefficient of about 20 dB represents a measurement of an AM depth of about 90%. For 40 dB reflection coefficient, the AM depth becomes 99%, difficult to be accurately measured.

IV. AM wave variable-screen modulator principle

The above proposed method can be improved by changing the test signal. Instead of a continuous wave can be used an AM wave. The modulation frequency of this test signal must be correlated with the VS angle transducer signal. Also, the phase of the modulation must be set in such manner to have the maximum incident wave for minimum reflected wave; this means a reverse phase angle. Considering the AM depth of the signal generator, m_{SG}, as been accurately adjustable, the variable part of the displayed signal will be described by the relations:

$$\left[(1+m_{SG}\cos\omega_{VS}t)\cdot\cos\omega_{SG}t\right]\cdot(1-m_{VS}\cos\omega_{VS}t)= \\ =\left[1-\frac{m_{SG}m_{VS}}{2}+(m_{SG}-m_{VS})\cos\omega_{VS}t-\frac{m_{SG}m_{VS}}{2}\cos 2\omega_{VS}t\right]\cos\omega_{SG}t \qquad (5)$$

where ω_{VS} and ω_{SG} are the angular frequency of the modulation signal and carrier signal respectively.

If the spectral amplitude corresponding to the modulation signal will be canceled, then will be obtained more effects:

- Finding of the modulation depth produced by VS and investigated phenomena: $m_{VS} = m_{SG}$;
- Computing of the wanted *RE* factor from (4);
- Other detectable effects are present, as minimizing of the spectral amplitude of the carrier and maximizing of the spectral amplitude of the first harmonic.

From simulation [7], this method appears as been successfully applicable until to 40 dB, Fig. 5.

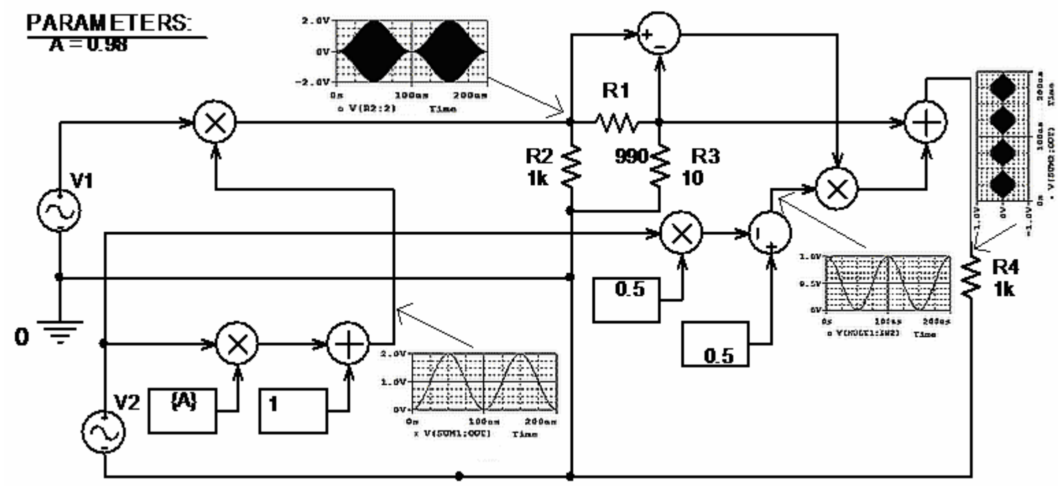

Fig. 5. PSPICE simulation diagram and waveforms for AM wave VS modulator principle.

In the presented simulation, the wanted parameter is represented by the voltage attenuation of the pi-network **R1÷R3** of 40 dB; the **A** parameter - having 0,98 as default value– represents m_{SG}; **V1** is the carrier signal source and **V2** is the modulator signal source. The modulation processes are implemented by multiplication, summarization and differences parts. In a parametric simulation sweep, for three value of **A** parameter, between 0,97 and 0,99, the FFT analysis of the response signal will lead to an optimum value of 0,98, see Fig. 6.

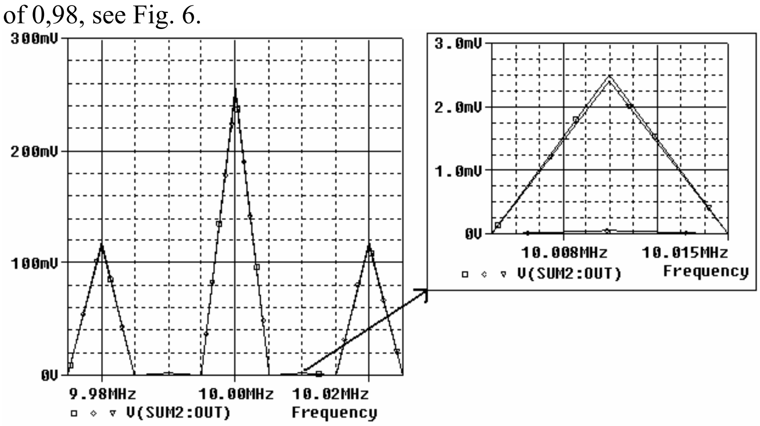

Fig. 6. Parametric analysis results for **A** values of 0,97, 0,98 and 0,99.

This means $m_{VS} = m_{SG} = 0,98$ and $RE_{[dB]} = -39,91$ instead of -40 dB. Besides of this good result obtained by simulation, was proved also the great sensitivity of this method specially, around of the wanted value, about 20 dB/percent of AM depth.

V. Conclusions

The free space measurement can be applied for materials having as first role the shielding by reflection or by absorption/reflection phenomena. By appropriate techniques, a single transmission/reception antenna can be used, simplifying the measurement procedure and the needed operations. Other techniques can extend the upper limits but a special device must be introduced beside the field probe. This device, called Variable Screen, must be developed for practical measurements on known absorbing materials or screens. The simulation has a great role in the study of the proposed methods. The powerful of this methods consist not necessary in the accuracy, but in the possibility to have for this kind of materials good results in true working conditions. In a future paper, the authors will present comparative practical results obtained by applying the described methods for known electromagnetic absorbing and shielding materials.

Acknowledgments

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