Research of power combining efficiency based on standing principle

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Abstract. Combining efficiency with previous research, this paper from the perspective of outgoing feeders start by analyzing a shipborne USB full-band solid state power amplifier VSWR test data, concluded: transmit power and there is a certain function of SWR, VSWR the frequency greater than 1.4 SSPA unable to meet the rated power value; and the presence of transmit power efficiency of certain synthetic function, synthesis efficiency is less than 0.8 of a solid-state amplifier frequency cannot meet the rated power value, and then find the VSWR as a function of the synthesis efficiency, That is the case of standing wave ratio greater than 1.4, the synthesis efficiency drops to 0.8, the standing wave ratio is less than 0.8, combining efficiency greater than 0.8. Finally, the improvement in ship-borne equipment feeder VSWR ratio effective way to improve the efficiency of the synthesis of shipborne equipment.

Introduction

Millimeter-wave amplifiers are millimeter wave transmitter radar, communications, electronic warfare systems, such as millimeter-wave measurement equipment and many essential components. Since the power supply requirements of modern high output power in the millimeter wave band, limited by the capacity of a single power amplifier tube, to achieve a large output power, it is widely used in power synthesis. The efficiency of synthesis is essential for the development of solid-state power amplifier so the research.

Fundamental

VSWR

In the signal transmission system, if the input resistance and impedance mismatch network power source, or a network output impedance mismatch with the load resistance, then the process of signal transmission, the mismatch in impedance due to reflection, a standing wave . In some point amplitude incident wave and the reflected wave phase stack, becoming the standing wave, while other points, the amplitude of the amplitude of the incident wave and the reflected wave reversal superimposition, becomes a node of a standing wave. The ratio antinodes and nodes of the standing wave is called a standing wave ratio, namely:

$$S = U_{\mathrm{F}} / U_{\mathrm{J}} \tag{1}$$

Two parameters on the right represent antinodes and nodal voltage standing wave ratio.

$$U_{\mathrm{F}} = U_{\mathrm{FWD}} + U_{\mathrm{REF}} \tag{2}$$

$$U_{\mathrm{J}} = U_{\mathrm{FWD}} - U_{\mathrm{REF}} \tag{3}$$

Right-hand sides of the two parameters are the incident and reflected voltage wave voltage. The reflection coefficient is expressed as:

$$\rho = U_{\mathrm{REF}} / U_{\mathrm{FWD}} = \sqrt{P_{\mathrm{REF}} / P_{\mathrm{FWD}}} = (Z_{\mathrm{C}} - Z_0)/(Z_{\mathrm{C}} + Z_0) \tag{4}$$

Formula Z0 is the characteristic impedance of the network, ZC load or source resistance, PREF and PFWD respectively incident power and the reflected wave power, so:

$$S = (U_{\mathrm{FWD}} + U_{\mathrm{REF}})/(U_{\mathrm{FWD}} - U_{\mathrm{REF}}) = (1+\rho)/(1-\rho) \tag{5}$$

Impedance mismatches cause reflections, due to the reflection of the load cannot fully absorb the energy of a power source to form a standing wave ratio.

Broadband power synthesis technology

Because the power of solid state devices is limited at a higher frequency band, it is necessary to have a power combiner network using a power synthesis technology, the ability to obtain higher power than the device. Power combiner is a combination of small power into a larger output power method; commonly used methods include die synthesis, synthesis and spatial synthesis circuit. Its power network synthesis by various two-way combiners constituted. Chain and branch structure of two general synthetic networks. Advantages chain structure is easy to change the number of ports. In order to add a port up to the existing structure, a coupling coefficient can be known coupler structure is applied to the chain, while the other couplers remain unchanged disadvantage of this construction is that the synthesis of a large number of sources, it is difficult composition coupler high coupling coefficient; branch line coupler or a coupling split T coupler a little too weak, coupled parallel line coupler is a bit too strong. Branched chain structure is not as flexible, but its coupling loss is small, so that when an increase in the number of high efficiency synthetic origin. In many applications, these two structures used in combination, can be a trade-off between flexibility and loss.

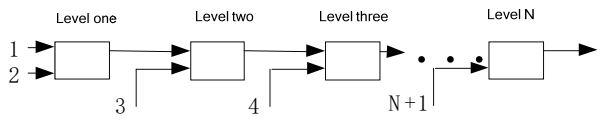

figure 1. Chain power combiner network

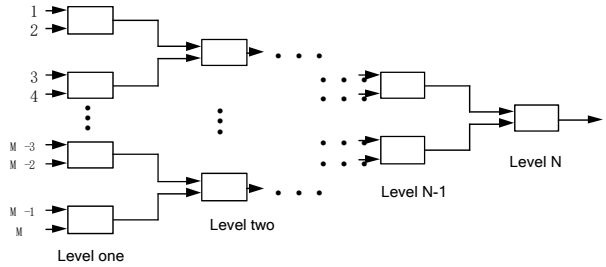

Figure 2. N-level-tap power combiner network

Experiment and Analysis

A ship carrying Unified Control System 800W SSPA consists of two mutual backup pre-preamplifier unit and four independent amplifier modules, the output power of a single amplifier unit is a maximum of 300W, the output power of the amplifier unit through four power synthesizer according to a certain ratio synthesis power combiner, the ultimate guarantee of the antenna output power 800W.

Wherein the emitter and reflected power dual-port coupler for detecting system and the detection signal to the monitor into me, into me monitor processor calculates the transmit power and the reflected power, and then displayed on the monitor screen, and then you can calculate the uplink feeder VSWR. The feeder VSWR test uses 1MHz stepping band is xx25 ~ xx20MHz, lower power is rated power, rated power cannot be met as far as setting the maximum output power value. In order to facilitate the analysis below only accessible within the scope of which xx25~xx70MHz data. Following through on a graph plotted experimental data analysis.

Figure 3 is a standing wave ratio curve and the total transmit power curve comparison chart. The abscissa is frequency, the left vertical axis is VSWR, transmit power on the right ordinate. As can be seen from the figure, the transmission power is not all system rated power 800W, 15 frequency points to 750W, 2 frequency points to 680W, a total of 17 points less than the rated power. If more than 17 points to set the transmit power frequency rated power 800W, single amplifier plug-in box will appear more than 300 watts of transmitting power, resulting in an alarm system, automatic power jump phenomenon. Carefully observe these deficiencies rated power frequency, can find these frequencies correspond generally larger feeder VSWR, all frequencies greater than VSWR 1.4 cannot meet the rated power value. It can be concluded one: standing wave has a greater impact

than the solid state power amplifier transmit power, cannot meet the standing wave ratio greater than 1.4 rated power value of frequency solid state amplifier.

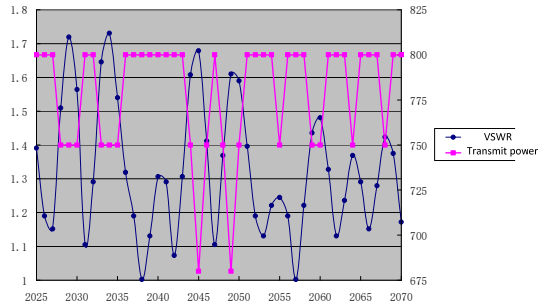

Figure 3. VSWR curve and the total transmit power curve comparison chart

Figure 4 is a graph combining efficiency and total radiation power curve comparison chart. The abscissa is frequency, the left vertical axis is the synthesis efficiency, the right vertical axis is transmission power. As can be seen from the figure, standing a U-shaped curve showing the change of time, combining efficiency will also exhibit a U-shaped change. All synthesis efficiency is less than 0.8 points transmit power does not satisfy the rated power. It can be concluded two: combining efficiency has great influence on the solid state power amplifier transmit power, frequency synthesis efficiency is less than 0.8 points SSPA unable to meet the rated power value.

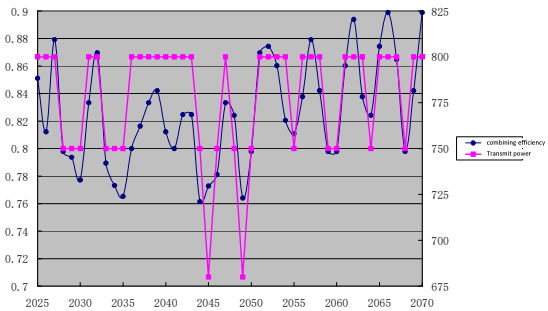

Figure 4. Synthesis efficiency curve and the total transmit power curve comparison chart

From the above analysis shows that the conclusion: there is a certain relationship between VSWR and transmit power can be expressed as P = F (s), ie transmission power is a function of VSWR. Combining efficiency exists a certain relationship with the transmission power, can be expressed as P = F (η), ie transmission power is a function of combining efficiency. The above two equations set of equations, a function will be obtained as follows: η = F (s), that is, combining efficiency is a function of VSWR. The following analysis of the relationship between them through specific data.

Figure 5 is a frequency - the frequency synthesis efficiency curve - VSWR curve comparison chart, the horizontal axis is the frequency, the left vertical axis is VSWR right ordinate synthetic efficiency. As can be seen from Figure 4 synthesis efficiency and VSWR ratio curve following relationship: VSWR case of large, low synthesis efficiency. VSWR is small, the high synthesis efficiency. Careful observation is not difficult to find, combining efficiency curve in Figure 3 and the standing wave ratio substantially symmetrical curve, the axis of symmetry of the standing wave ratio is equal to 1.4, combining efficiency equal to 0.8 connections. It can be concluded three: For the standing wave ratio greater than 1.4 frequency synthesis efficiency is less than 0.8; VSWR less than 1.4 for the frequency, combining efficiency greater than 0.8.

Different devices may have different results, but it is certain that the standing wave ratio becomes large to bring much greater than the power loss caused by the reflected power increases the power loss, VSWR becomes larger decline means that bring efficiency It is obvious.

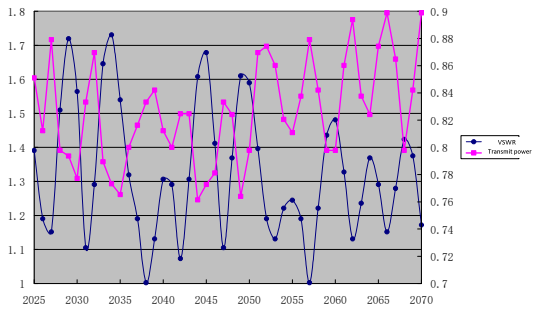

Figure 5. Combining efficiency curve and VSWR curve comparison chart

The above analysis can be found, power combining efficiency depends not only on the phase error, envelope delay, amplitude error, the performance of the synthesizer itself, but also the feeder and output VSWR of a relationship. Improve the efficiency of the synthesis can be transformed into ways to adjust the feeder impedance matching is not good cause signal reflections, the power input to the synthesizer will be reduced, it is generally to minimize the standing wave ratio of each device, so try standing wave feeder small, improve the efficiency of power combining. In order to improve the synthesis efficiency as much as possible, to reduce transmission line losses and VSWR is designed and developed high-power amplifier important and difficult. Of particular note is the transmission lines and the conversion is a key part of the connecting portion is generally caused by deterioration of the standing wave, the VSWR must be less than 1.4.

Summary

a. A solid state power amplifier for the presence of numerous unable to meet the rated power frequency problems, you can adjust the feeder VSWR achieve power combining efficiency, thereby reducing the individual transmit power amplifier plug-in box, troubleshooting.

b. Shipborne equipment temperature and humidity changes in the larger environment, you need to regularly check the work of the inflator and desiccant inflator, when found in the desiccant should be replaced immediately change color or remove fried dry, avoid moisture ingress has caused feeder VSWR change Big.

c. Shipborne equipment vibration shaking larger, the need for regular check fastening is good feeders, feeder without injury, sealing is good, to prevent the feeder connection position caused by the change becomes large standing wave feeder.

d. Voltage standing wave ratio is an important indicator of antenna feeder system, whether newly opened or microwave circuits of the running circuit should be measured standing wave ratio for the index does not meet the antenna feeder must be carefully examined and remediation, otherwise it will cause echo interference, the circuit will cause severe interruption.

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