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I. INTRODUCTION TO SMARTRADAR 970 SmartRadar ATi

Table of contents

1.0 Introduction
1.1 Principle of Pulse Radar
1.2 Principle of Synthesized Pulse Radar
1.3 Synthesized Pulse Radar
1.4 Adaption of Antennas
1.5 False Ref1ections
1.6 Frequency Sweep
2.0 Construction
3.0 Technical Data
3.1 Materials –Housing
3.2 Power ratings
4.0 Safely Measures
4.1 Electronic boards
4.1.1 Optional Plug-In intrinsic safe modules
4.2 Antenna Types
5.0 Additional Safety Precautions
5.1 Electrostatic Discharge
5.2 Maximum Radiated Energy

II. OPERATION PRINCIPLES

I) Operation principle SmartRadar
II) Advanced Radar Transceiver
III) Basic layout SmartRadar
IV) Overview antennas
V) Free Space Antennas
VI) Stilling Well Antennas
VII) High Temperature Antennas
VIII) Summary SmartRadar LT

III. EQUIPMENT AND MODULE PHOTOGRAPHS

A. Board ICU
B. Board RF3-DAB.
C. Shielding removed from RF3-DAB
D. Option Board ICU
E. Board GPS
F. Option Board RS 232C / RS 485
G. Option Board Hart 4-20 mA
H. SmartRadar

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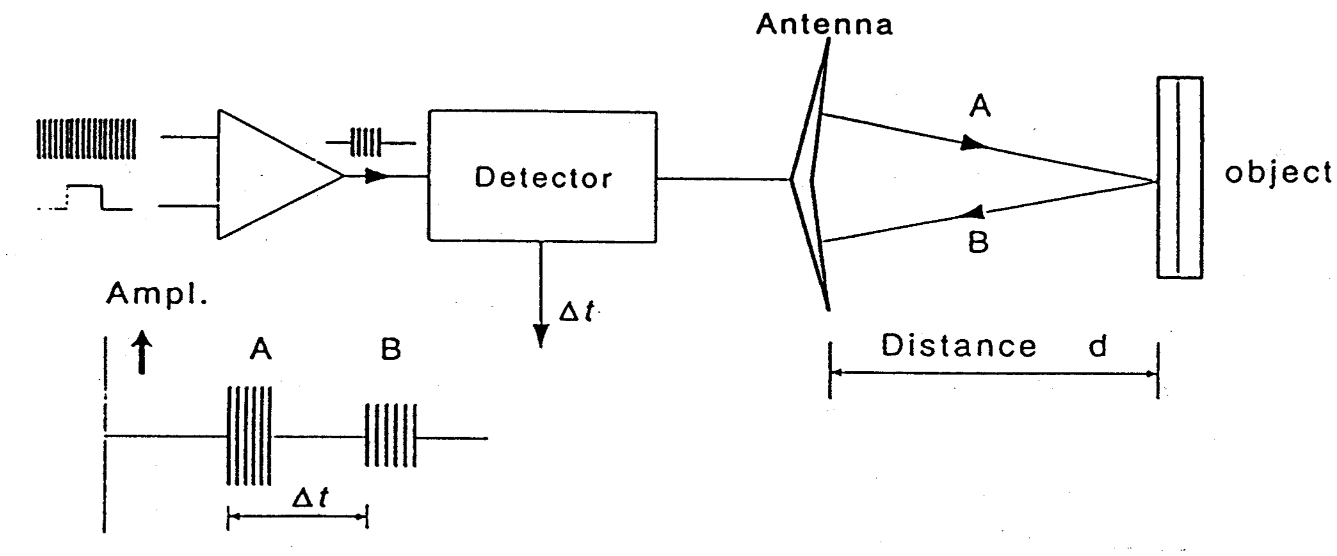
Enraf 970 SMARTRADAR

1.0 INTRODUCTION

The Enraf 970 SmartRadar level gauge is a further development of the Enraf 973 SmartRadar level gauge. The 973 level gauge is granted equipment authorisation FCC Identifier LOM973SR.
The 970 is designed to measure the level of liquid in storage tanks. Measurement is based on Digital Planar Technology (DPT) that is the combination of digital signal processing with innovative planar antenna technology. This antenna sends and receives the beam that is reflected by the surface of the product contained in the storage tank. The phase shift between the transmitted and a reflected signal is used to detect the distance to the liquid surface.

1.1 PRINCIPLE OF PULSE RADAR

The investigations made in order to overcome the disadvantages of Pulse Radar that was used in World War II resulted in the development of the ENRAF 873 and 970 level gauges. A pulse radar releases a burst of high frequency electromagnetic signal. The modality of reflecting a microwave signal off a stored liquid level enables the distance to be measured and converted to level of a storage vessel. The relative short distances in storage tank applications require an extremely high resolution and exceptionally stable and accurate timers complicating this technique (Figure 1).



$\Delta t = \frac{2d}{c}$ where c = speed of light [m/s] $\longrightarrow$ $d = 1/2 \ . \ \Delta t \ . \ c$

Example: $\Delta t = 60\ \mu s.$ $\longrightarrow$ $d = 1/2 \ . \ 60.10^{-6} \ . \ 3.10^{8} = 9000$ m.

Figure 1 Principle Pulse Radar

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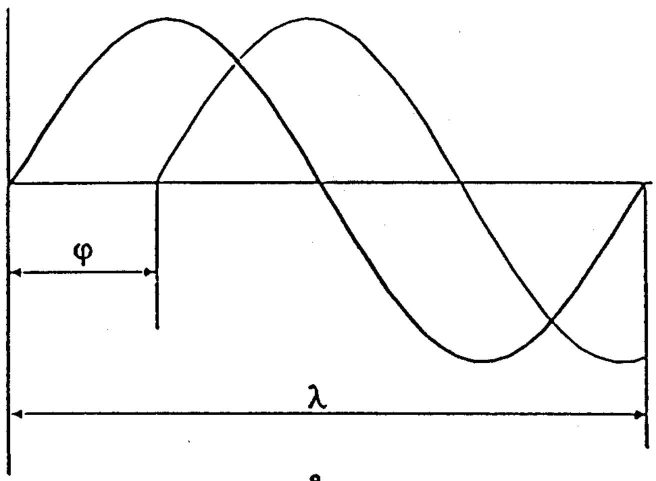
1.2 PRINCIPLE OF SYNTHESISED PULSE RADAR

Distance measured by microwaves can also be done using the phase shift principle, which requires a stable fixed frequency. When this signal is reflected by the stored liquid level and received by the antenna. a phase shift occurs between the original signal and the reflected signal. This phase shift, plus the number of complete wavelengths is propol1ional to the distance. It becomes clear that radar gauging could in theory, be achieved by raising and lowering a reflector from the antenna towards the liquid surface and counting the number of zero crossing the phase shift. Basically this method or principal is obviously not suitable for tank gauging (Figure 2).



$\lambda = \frac{c}{f}$ $\quad f = 10GHz \longrightarrow \lambda = \frac{3.10^8}{10.10^9} = 0.03m$ or 30mm

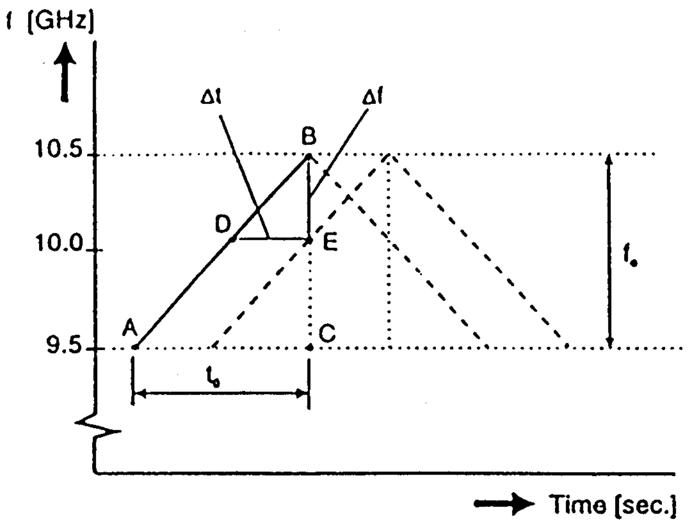
For measurements above 30mm $\longrightarrow$ $K\lambda + \varphi$

K= number of complete wavelengths
λ = wavelength of the radar signal
φ = phase shift within one wavelength

Figure 2 Measuring distance through phase shift

1.3 SYNTHESISED PULSE RADAR

Ultimately the solution for tank gauging is Synthesized Pulse Radar (SPR), a combination of pulse radar and the phase shift principal. In theory at a fixed distance frequency A will generate a phase shift. At the same fixed distance, a frequency B will also generate a phase shift and so on. Using more fixed frequencies and knowing that each frequency will return a different phase shift, the distance can be calculated. The most effective method is to generate frequency sweeps, which will be reflected by the liquid surface and received by the antenna a short time later (Figure 3). Also shown in Figure 3, is the calculated value of the "System Gain" which is a measure of the distance between the antenna and the liquid level.



Line AC represents sweeptime t_0
Line BC represents frequency sweep f_0
Line DE represents travel time Δt
Line BE represents frequency difference Δf

$$\frac{BE}{BC} = \frac{DE}{AC} \text{ or } \frac{\Delta f}{f_0} = \frac{\Delta t}{t_0} \longrightarrow \Delta f = \frac{\Delta t \cdot f_0}{t_0}$$

as with Pulse Radar $\Delta t = \frac{2d}{c}$

Hence $\Delta f = \frac{2f_0 . d}{c . t_0} = k_M . d \longrightarrow k_M = 66.66....\text{Hz/m}$

(k_M is named SYSTEM GAIN)

Figure 3 Principle of synthesized Pulse Radar

1.4 ADAPTION OF ANTENNAS

The adaption of parabolic and cone shaped antennas can be used for this application. However, research by ENRAF lead to the introduction of Digital Planar Technology (DPT) for tank gauging applications. This technology (originally developed for space satellites), has proven to be a most suitable and accurate application for tank gauging. Digital Planar Technology antennas are small and sturdy, and their lightweight simplifies the installation on storage tanks and vessels.

1.5 FALSE REFLEXIONS

In actual applications, not only the liquid surface gives a reflection, but also there is an abundance of “false” reflections. Within the tanks wall rebounds, bottom-and construction beams are a example of what causes these reflections. The most important task is to find out which frequency represents the actual liquid level. Conventional signal processing makes use of analog filters. However, analog techniques are prone to temperature drift and the method of controlling the drift can be quite troublesome when making a. product for installation under worldwide locations. Enraf engineers developed this device using Digital Signal Processing (DSP).

1.6 FREQUENCY SWEEP

In the 970 SmartRadar ENRAF engineers developed a frequency sweep output while simultaneously sampling the measurement signal at a rate of over 20.000 samples per second. After sampling all basic frequencies are calculated with their amplitudes representing al reflections in the tank. This exercise is fully digital and is carried out by builtin microprocessors. It is obvious the Digital Signal Processing (DSP) is faster and more accurate. It offers a great advantage over conventional analog signal processing because it does not require cumbersome temperature compensation. In addition, an internal reference is used making it unnecessary to keep the electronics at a controlled high temperature such as is required with analog processing.

2.0 CONSTRUCTION

The 970 SmartRadar level gauge consists of an electronic compartment and an incorporated terminal compartment; meeting or exceeding safety protection as per the national fire code Class I, Div. I. Groups C and D for explosive zones. The unit contains all electronics necessary to generate and process the microwave and reflected signals that it receives.
The electronics are mounted on printed circuit boards. The gauge can communicate with data handling systems via a galvanic isolated and shielded transformer, separated transmission lines, or via an optical electronic coupler mounted in the wall of the housing.

The unit is coupled to the antenna via a microwave adaptor and coupling. The shape of the coupling and the antenna may vary dependent of the antenna type to be used.

3.0 TECHNICAL DATA

3.1 MATERIALS -HOUSING

Aluminium (A 356 or better)
Stainless (ANSI 304 or better)

3.2 POWER RATINGS

Nominal voltage:	85 - 264 Vac, 50/60 Hz (+/- 10 %), or, 18 – 72 Vdc
Power consumption:	25 VA max.
Infra red connection:	< 7 mW

<u>Radiated power</u>

frequency:	10 GHz
sweep:	approx. 1.4 GHz
nominal radiated power:	0,6 mW
theoretical max. power:	2,5 mW
Antenna Type	Planar
Antenna Input	15 V (supplied by control unit)
Antenna Temperature	-40° to +248° F -320° to +390° F for H04
Antenna Pressure	-7 to 100 psi Up to 600 psi for H04
Measurement Type Synthesized Pulse	Frequency Modulated
Signal Processing (DSP)	Full Digital Signal Processing
Accuracy	= 0.04 inches
Measurement Range	0.5 to 131 feet

Resolution	0.0004 inches
Temperature Range (Electronics)	-40° to +185° F

4.0 Safety Measures

The electronic compartment and terminal compartment are constructed in protection type explosion proof. The flamepaths between covers and compartments are threaded. The covers are provided with socket head screws in order to secure the covers against loosening.

The opto-electronic coupler is mounted in the wall of the electronic compartment. The flamepath between the coupler and the enclosure wall is threaded. The coupler is provided with a glass window. The window is mounted in a bore and kept in position by a rim at one side and by a spring ring at the other side. In order to avoid ingress of moisture the gap between glass window and the wall of the bore has been filled up and glued with a sealant. The coupler is secured against loosening by a socket head screw at the inside of the enclosure.
The wire harnesses are fed from the electronic compartment to the terminal compartment via 2 wire transit plugs. One wire transit plug is used for the intrinsic safe wiring and is indicated by a blue colour, the other wire transit plug is used for the non intrinsic safe wiring only.
The dimensions of the flamepaths and tolerances of the threads comply with ISO 965/1 and ISO 965/III Class 2.

A wave transmitter feeds the high frequency power to the antenna. The assembly consists of a wave transmitter assembly that consist of a wave transmitter bushing with glued-in rod made of quartz glass. The assembly is glued in the housing and additionally secured by socket head screws.
The quartz glass rod protected against shifting out of the bore by a rim. The antenna feeder assembly is of similar construction.
The antenna itself is available in several variations depending upon the application.

The terminal compartment is provided with approved and certified terminals for the connection of both intrinsic and non-intrinsic safe field terminations. For the connection of the intrinsic safe circuits, blue terminals are used.
The terminal compartment is provided with five 3/4 inch NPT threaded openings for the connection of certified explosion proof cable glands or conduit systems.

4.1 ELECTRONIC BOARDS

The unit is equipped with:

Print ICU	Integrated control unit
Print ICU-RS232/485 (option)	RS232/485 communication board
ICU-GPS 85-264 or,	AC supply board or,
ICU-GPS 18-72	DC supply board
Print RFB3-DAB	radar frequency and data acquisition board
ICU HPI Hart1/Hart2/Spot (options)	hart processing and temperature input board
Print ICU-HPO (option)	hart processing output board

4.1.1 OPTIONAL PLUG-IN INTRINSIC SAFE MODULES

The 970 can be provided with one optional plug in modules to measure the temperature or pressure in a pipeline or storage tank. The optional boards will be mounted on the HPI board within the unit.
All connections and wiring to the intrinsic safe boards are galvanically separated from al1 other connections and wiring. In order to obtain suitable separation, the wire harness to the intrinsic safe boards are separated from the intrinsic safe wiring by sufficient clearance and creepage distances.

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The harness is fed through the wall between the radar electronics compartment and terminal wires. The terminals for the field connection of the non-intrinsic safe circuits and the terminals for the field connections to the intrinsic safe circuitry are separated, providing clearance and creepage distance. The optional modules are an independent system. They are serviced by the same power supply and that they share the same data output link either by the two wire bi-phase mark system or via the optical coupling to the hand held Portable Enraf Terminal (PET).

4.2 ANTENNA TYPES

Free Space
FO6, F08, T06, W06, D02
For free space applications the antenna can be mounted on a roof nozzle or manhole. (Sec antenna literature section).
Stilling Well
S06, S08, S10 and S12
For stilling well applications the antenna can be mounted using a stilling well in the tank. (See antenna literature section).
High Pressure
H02 and HO4
For high pressure applications up to 600 psi.(See antenna literature section).

5.0 ADITIONAL SAFETY PRECAUTIONS

The level gauge antennas are developed for direct mounting in the gas atmosphere of a storage tank or vessel. The design allows a wide range of physical sizes, which is dependent upon the available opening size, temperature and pressure in the storage vessel. In order to avoid migration of gasses from the storage tank to the antenna unit, the wave transmitter assembly is provided with a coupling that offers free vent to atmosphere. To avoid ignition sources in the tank atmosphere several measures have been taken as will be reported in 5.1 and 5.2.

5.1 ELECTROSTATIC DISCHARGE

AII parts of the antenna in contact with the product vapour have either a surface resistance of less than on mega ohm or the surfaces are provided with tracks of conduction material such that the resulting surfaces are smaller than 25 square millimetres. The outside of the enclosure is provided with protective earth terminals to assure equal potential with the tank structure. The enclosure is additionally protected against corrosion by alodine treatment providing a conductive protective layer.

5.2 MAXIMUM RADIATED ENERGY

The maximum radiated energy in the tank atmosphere is limited to 1.6 mW. As the antenna will be installed inside an enclosed grounded metal container, there is no possibility that any signal could or would be transmitted outside of the tank. The power output is limited by the selection of electronic components that generate the high frequency power in combination with the wave transmitter that constitutes a high frequency filter. In theory, the maximum dissipation that could be generated by the driver before breakdown equals 1.6 mW. Those frequencies below 6 Giga Hertz need not to be considered, as these frequencies will not be transmitted via the wave transmitter.

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